Appendix F3. Plan Area Sediment Delivery Estimates: A Model and Results

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F3.1 INTRODUCTION

A sediment delivery model was developed to:

- Consolidate information from the landslide assessment (Appendix F1) and road sediment source inventory (Appendix F2);
- Combine the findings from the above mentioned studies to produce an approximate sediment delivery estimate for the Plan Area;
- Compare sediment delivery for the “No Plan” versus Plan scenarios;
- Evaluate the statistical efficiency and effectiveness of the various conservation measures; and
- Assess the variation in sediment delivery due to the “uncertainty” or “ranges” associated with key assumption variables using Monte Carlo simulation techniques;

F3.2 A CONCEPTUAL SEDIMENT DELIVERY MODEL

A simple conceptual model was developed to integrate the various sources of data and to produce a partial sediment summary for the Plan Area (see Figure F3-1 below). The model does not include all sources of sediment. It only attempts to model the sediment produced from shallow and deep-seated landslides (see Appendix F1) and high and moderate priority sites associated with roads (see Appendix F2). These are (1) sources of sediment not directly addressed by the implementation of best management practices (BMPs), (2) sources of sediment that were studied in sufficient detail such that empirical models could be constructed, and (3) potential sediments that could be effectively addressed by the conservation measures proposed pursuant to this Plan to mitigate the impacts of the covered activities.

The sources of sediment not directly addressed in this simple model include sediment produced from surface erosion and sediment produced from stream bank erosion. It should be noted, however, that the Road Implementation Plan includes measures to address and correct potential surface erosion associated with high and moderate priority treatment sites. Thus, this potentially prolific source of fine sediment will be treated and its impacts to aquatic species largely eliminated by the end of the 50-year term of the Plan.

This simple property-wide model is based on expected 50-year (long-term) average sediment delivery rates. (The model was developed to assess property-wide sediment delivery issues. The model does not have a spatial component and, therefore, is not able to make site-specific sediment delivery predictions.) It is recognized that the annual variation in such rates may be large and lead to annual sediment delivery amounts that are much greater or much smaller than the averages contained within this model. A model that accounts for such variation would have been unwieldy (if not impossible) to construct and problematic to parameterize given the nature of the sediment delivery studies described in Appendices F1 and F2.

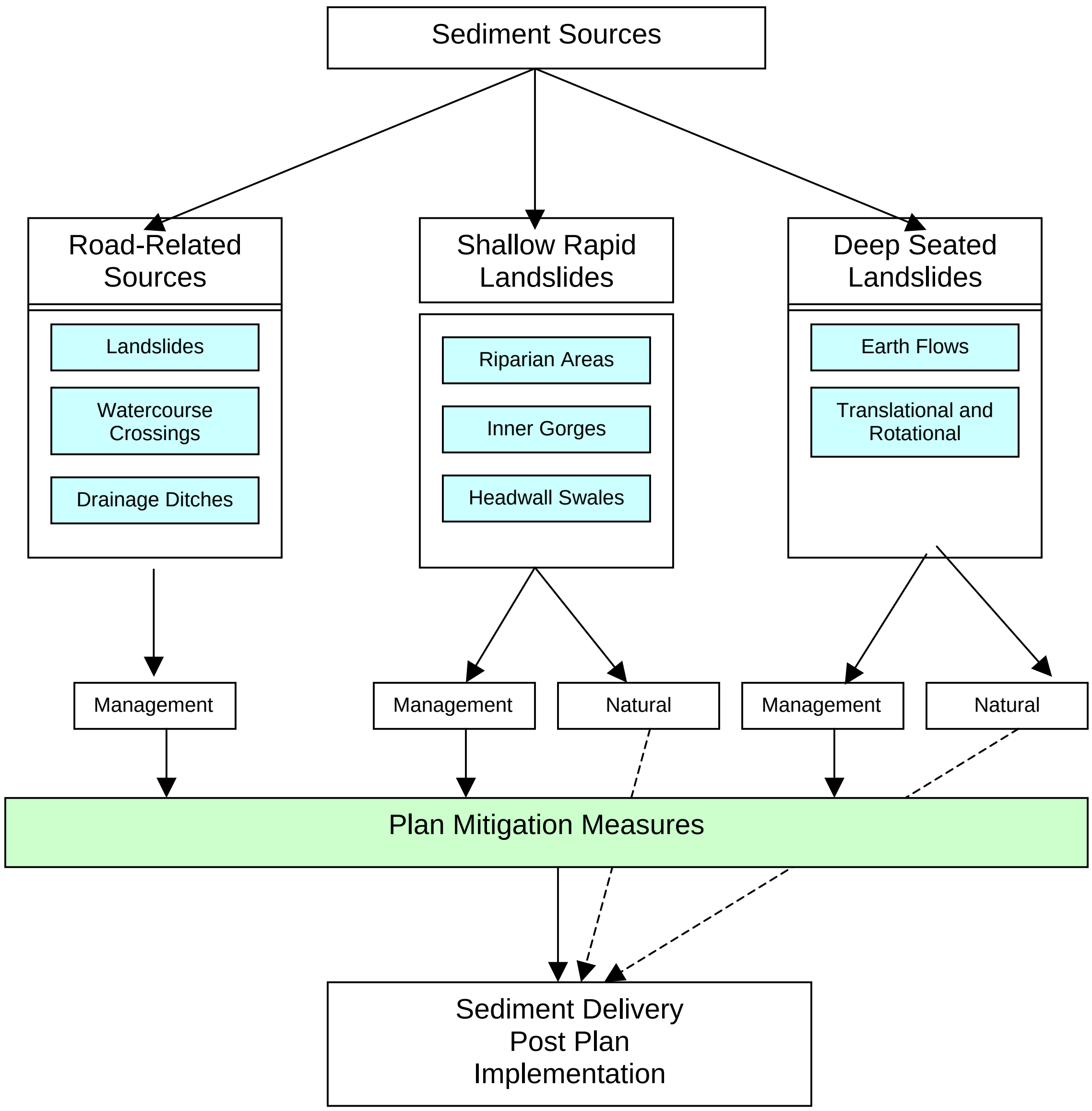


Figure F3- 1. Conceptual model of integration of data for partial sediment summary for Plan Area.

In any event, even if such a model could be constructed, its computed 50-year averages would be comparable to the output generated by the simple model described herein. Thus, the management options and conservation measures that evolve from the use of the model described in this appendix are entirely appropriate provided they are implemented over the 50-year term of the Plan to produce the desired results.

This conceptual model was used as the basis for developing a spreadsheet model that integrated the various data sets compiled for the Plan.

F3.3 ROAD-RELATED SEDIMENT SOURCE DATA

The road sediment source inventory conducted by PWA covered five watersheds: Salmon Creek, Rowdy Creek, McGarvey Creek, Redwood Creek, and Little River. The following table (Table F3-1) shows how the information from these watersheds (see Appendix F2 for watershed specific details) was combined to produce estimates for the Plan Area. The basic idea was to use an estimate of Plan Area road length (4,311 miles) as a multiplier to produce potential sediment totals for the Plan Area. For example, the current GIS estimate of road miles in the Plan Area is 4,311. Plan Area potential sediment from road-related landslides would be determined as follows:

$$1{,}456{,}862 \text{ yd}^3 = 4{,}311 \text{ miles} \times 338 \text{ yd}^3\text{/mile}$$

(Note: The spreadsheet model carries many digits beyond the decimal point so the math may not appear to “work out” properly in the equation above or the table below.) Only potential sediment from high and moderate treatment priority sites is used in the analysis, as it is these sites that are targeted for repair under the Road Implementation Plan.

As part of the sediment inventory, PWA provided Green Diamond with treatment costs (Table F3-2) that were used as the basis to determine the amount of sediment that could be stabilized using $2.5 million as specified under the Road Implementation Plan—approximately 204,000 cubic yards. An important consideration in this calculation is the efficiency that is realized by appropriately prioritizing the work and focusing on concentrations of high and moderate priority treatment sites. Such prioritization will allow Green Diamond to stabilize approximately 48% of the potential sediment during the first 15 years of the Plan with the $2.5 million annual commitment.

Several of the variables associated with the road sediment source inventory were assigned an appropriate range for purposes of conducting the Monte Carlo simulation exercise. These variables and their ranges are listed below in the VARIABLE RANGES section of this appendix. An example is the range associated with the miles of road contained within the Plan Area. Green Diamond recognizes that some roads have not been mapped and are not contained in Green Diamond’s GIS. To account for this understatement of Plan Area road miles, an assumption called the “road miles blow up factor” was devised. This factor was assigned a triangular distribution with a minimum increase of 10%, a most likely increase of 15%, and a maximum increase of 25%. The mean of this distribution, 16.7%, was used in the calculations to produce Tables F3-1 and F3-2. That is,

$$4{,}311 \text{ miles} = 116.7\% \times 3{,}695 \text{ miles},$$

where 3,695 miles is the length of roads according to Green Diamond’s GIS.

Table F3-1 Potential road-related sediment delivery from high and moderate treatment priority sites.[1]

	Road Length (mi)	Potential Sediment Delivery From Watercourse Crossings		Potential Sediment Delivery From Landslides		Potential Sediment Delivery From "Other sites"		Total Potential Sediment Delivery	
		yd^3	yd^3/mi	yd^3	yd^3/mi	yd^3	yd^3/mi	yd^3	yd^3/mi
Inventory Total from Five Watersheds	518	589,236	1,138	175,060	338	9,127	18	773,423	1,493
Estimate for the Plan Area	4,311	4,903,664	1,138	1,456,862	338	75,956	18	6,436,482	1,493

1 The inventory totals were extracted from Table F2-2 in Appendix F2. The Plan Area sediment delivery estimates are based on the inventoried rates (cubic yards per mile) multiplied by an estimate of the total miles of roads within the Plan Area.

Table F3-2. Calculation of the sediment stabilization effort for the Plan Area.[1]

	Watercourse Crossings	Landslides	Other	Total
Total sediment (yd^3)	4,903,664	1,456,862	75,956	6,436,482
Cost/yd^3	$15.69	$7.57	$54.24	$14.31
Total cost	$76,938,495	$11,028,445	$4,119,829	$92,086,769
48% of total sediment	2,329,708	692,148	36,086	3,057,943
Cost/yd^3	$13.45	$6.49	$46.49	$12.26
41% of total cost	$31,331,250	$4,491,054	$1,677,696	$37,500,000
Sediment stabilization effort (yd^3)	155,314	46,143	2,406	203,863
Cost/yd^3	$13.45	$6.49	$46.49	$12.26
Annual cost	$2,088,750	$299,404	$111,846	$2,500,000

1 The cost per cubic yard figures in this table is slightly larger than those shown Table F2-3. These cost adjustments were made to account for an underestimate in the basic data as described in Table F2-6.

Other road-related assumption variables that were assigned distributions (see Table F3-13) include:

- Delivery from road-related landslides
- Delivery from road-related watercourse crossings
- Delivery from road-related “other” sites
- Cost to fix watercourse crossing sites
- Cost to fix landslide sites
- Cost to fix “other” sites
- Road upgrade effectiveness factor

F3.4 WATERSHED SEDIMENT SUMMARIES AND PLAN AREA SEDIMENT DELIVERY ESTIMATES

Sediment delivery summaries for the Hunter Creek, Salmon Creek, Litter River, and Upper Mad River pilot watersheds are shown in Tables F3-3, F3-4, F3-5, and F3-6, respectively. These tables are based on the results of an assessment of long-term landslide sediment presented in Appendix F1. The sediment delivery summaries show how sediment is partitioned among three sources of sediment—roads, shallow landslides, and deep-seated landslides—contained in the conceptual model. (Note: The Upper Mad River watershed summary only shows sediment delivery estimates for deep-seated landslides.) The purpose of this section is to explain how these data were combined to derive appropriate sediment delivery estimates for the Plan Area.

Tables F3-3, F3-4, F3-5, and F3-6 are largely restatements of results presented in Appendix F1 (see Tables 15, 16, and 17) in a format that conveniently summarizes the modeled sources of sediment delivery and shows the reduction in sediment delivery that is expected to occur as a result of implementing the Plan's conservation measures. The road-related sediment delivery estimates, as discussed in detail below, are based on data presented in Appendices F1 and F2.

The data from these four pilot watersheds were combined to derive sediment delivery estimates for the Plan Area. This was accomplished by developing factors (or weights) that represent how much of the Plan Area is similar to each of the pilot watersheds. Such Plan Area factors were developed by examining the landslide processes acting within each of the unstudied sub-watersheds based on a review of terrain maps, geologic maps, available landslide maps, discussions with Green Diamond foresters, and observations made by a Registered Geologist during a year 2000 helicopter flyover of the Green Diamond property. The percentages of each pilot watershed were then assigned to each sub-watershed based on the criteria listed above. The results of this Delphi technique exercise are summarized in Table F3-7. The last row of Table F3-7 shows the Plan Area factors. This row was determined by multiplying the sub-watershed acreages by the pilot watershed percentages and then summing the results. Note that there are separate factors for shallow landslides and deep-seated landslides.

To illustrate the use of the Plan Area factors in Table F3-7 (see the last row of the table), consider the calculation of the expected sediment delivery that will come from Plan Area RMZs prior to implementation of the Plan (Pre-Plan estimates). To do this, the data from these three representative watersheds will be combined to develop an estimate for 394,675 timberland acres. From Tables F3-3, F3-4, and F3-5, the sediment delivery estimates for RMZ areas are 235 yd^3/yr, 798 yd^3/yr, and 768 yd^3/yr for the Hunter Creek, Salmon Creek, and Little River watersheds, respectively. The total acres within each of these watersheds, also shown in the tables, are 10,126 acres, 7,889 acres, and 28,755 for the Hunter Creek, Salmon Creek, and Little River watersheds, respectively. The appropriate equation, therefore, is

$$\begin{aligned} 13{,}200\ yd^3/yr = 394{,}675\ \text{acres} * [&0.312*(235\ yd^3/yr \div 10{,}126\ \text{acres}) \\ &+ 0.105*(798\ yd^3/yr \div 7{,}889\ \text{acres}) \\ &+ 0.583*(768\ yd^3/yr \div 28{,}755\ \text{acres})] \end{aligned}$$

Table F3-3. Hunter Creek sediment delivery summary. SMZ buffer widths are based on a cumulative sediment delivery volume of 80%. The sediment numbers in the table represent the total annual sediment delivery expected from the watershed. Note that natural and management related sediment delivery estimates are provided for both the pre- and post-Plan conditions.

	Sediment Split (roads vs. harvest)	Sediment Split	Mgt vs. Natural Sediment Under Current Practices	Effect of Plan Measures	Percent Acres in Zone	Acres in Zone	Pre-Plan Sediment Delivery (cu yds/yr)	Pre-Plan Natural Sediment (cu yds/yr)	Pre-Plan Mgt Sediment (cu yds/yr)	Post-Plan Sediment Delivery (cu yds/yr)	Post-Plan Natural Sediment (cu yds/yr)	Post-Plan Mgt Sediment (cu yds/yr)
Roads	54.8%	100.0%	100.0%	96.1%			4,465	0	4,465	173	0	173
Hillslope Shallow Landslides (extracted from Tables 15 and 16 in Appendix F1)	42.7%											
RMZs		6.8%	19.0%	95.4%	14.7%	1,489	235	191	45	193	191	2
SMZs		20.1%	50.0%	58.6%	3.5%	356	697	349	349	493	349	144
SHALSTAB		34.2%	60.0%	60.0%	13.1%	1,324	1,190	476	714	762	476	286
Other		39.0%	50.0%	0.0%	65.4%	6,621	1,355	677	677	1,355	677	677
Deep Seated Landslides (extracted from Table 17 in Appendix F1)	2.6%											
DSL Total		100.0%	2.6%	15.0%	3.3%	338	210	205	5	209	205	5
Total Sediment Delivery (Note that Total Acres is shown in one column)						10,126	8,153	1,898	6,255	3,184	1,898	1,287

Table F3-4. Salmon Creek sediment delivery summary. SMZ buffer widths are based on a cumulative sediment delivery volume of 60%. The sediment numbers in the table represent the total annual sediment delivery expected from the watershed. Note that natural and management related sediment delivery estimates are provided for both the pre- and post-Plan conditions.

							Pre-Plan			Post-Plan		
	Sediment Split (roads vs. harvest)	Sediment Split	Mgt vs. Natural Sediment Under Current Practices	Effect of Plan Measures	Percent Acres in Zone	Acres in Zone	Sediment Delivery (cu yds/yr)	Natural Sediment (cu yds/yr)	Mgt Sediment (cu yds/yr)	Sediment Delivery (cu yds/yr)	Natural Sediment (cu yds/yr)	Mgt Sediment (cu yds/yr)
Roads	23.6%	100.0%	100.0%	96.1%			842	0	842	33	0	33
Hillslope Shallow Landslides (extracted from Tables 15 and 16 in Appendix F1)	55.5%											
RMZs		40.2%	23.8%	99.8%	8.8%	698	798	608	190	608	608	0
SMZs		0.1%	50.0%	60.0%	0.3%	21	2	1	1	1	1	0
SHALSTAB		13.5%	60.0%	60.0%	3.0%	234	268	107	161	172	107	64
Other		46.2%	50.0%	0.0%	54.2%	4,279	916	458	458	916	458	458
Deep Seated Landslides (extracted from Table 17 in Appendix F1)	20.9%											
DSL Total		100.0%	5.6%	15.0%	33.7%	2,657	748	706	42	741	706	35
Total Sediment Delivery (Note that Total Acres is shown in one column)						7,889	3,574	1,880	1,693	2,471	1,880	591

Table F3-5. Little River sediment delivery summary. SMZ buffer widths are based on a cumulative sediment delivery volume of 60%. The sediment numbers in the table represent the total annual sediment delivery expected from the watershed. Note that natural and management related sediment delivery estimates are provided for both the pre- and post-Plan conditions.

							Pre-Plan			Post-Plan		
	Sediment Split (roads vs. harvest)	Sediment Split	Mgt vs. Natural Sediment Under Current Practices	Effect of Plan Measures	Percent Acres in Zone	Acres in Zone	Sediment Delivery (cu yds/yr)	Natural Sediment (cu yds/yr)	Mgt Sediment (cu yds/yr)	Sediment Delivery (cu yds/yr)	Natural Sediment (cu yds/yr)	Mgt Sediment (cu yds/yr)
Roads	40.4%	100.0%	100.0%	96.1%			2,377	0	2,377	92	0	92
Hillslope Shallow Landslides (extracted from Tables 15 and 16 in Appendix F1)	29.4%											
RMZs		44.3%	23.1%	99.4%	13.3%	3,815	768	590	177	592	590	1
SMZs		1.8%	50.0%	60.0%	0.3%	74	31	16	16	22	16	6
SHALSTAB		11.2%	60.0%	60.0%	2.5%	725	195	78	117	125	78	47
Other		42.7%	50.0%	0.0%	65.5%	18,830	740	370	370	740	370	370
Deep Seated Landslides (extracted from Table 17)	30.2%											
DSL Total		100.0%	3.2%	15.0%	18.5%	5,311	1,779	1,722	56	1,770	1,722	48
Total Sediment Delivery (Note that Total Acres is shown in one column)						28,755	5,889	2,776	3,113	3,340	2,776	564

Table F3-6. Upper Mad River sediment delivery summary. The sediment numbers in the table represent the total annual sediment delivery expected from the watershed. Note that natural and management related sediment delivery estimates are provided for both the pre- and post-Plan conditions. This is a "partial" summary because only sediment from deep seated landslides is included in the table.

	Sediment Split (roads vs. harvest)	Sediment Split	Mgt vs. Natural Sediment Under Current Practices	Effect of Plan Measures	Percent Acres in Zone	Acres in Zone	Pre-Plan			Post-Plan		
							Sediment Delivery (cu yds/yr)	Natural Sediment (cu yds/yr)	Mgt Sediment (cu yds/yr)	Sediment Delivery (cu yds/yr)	Natural Sediment (cu yds/yr)	Mgt Sediment (cu yds/yr)
Roads												
Hillslope Shallow Landslides												
RMZs												
SMZs												
SHALSTAB												
Non-Protected Areas												
Deep Seated Landslides (extracted from Table 17 in Appendix F1)	100.0%											
DSL Total		100.0%	14.9%	15.0%	41.2%	1,918	902	767	135	882	767	115
Partial Sediment Delivery (Note that Total Acres is shown in one column)						4,658	902	767	135	882	767	115

Table F3-7. Factors used to derive Plan Area sediment delivery estimates from the four pilot watersheds. The factors in this table represent that portion of the Plan Area that can be adequately characterized.

Road Planning Watershed	Acres	HPA Group	Shallow Landslide Division			Deep-Seated Landslide Division			
			SC	LR	HC	SC	LR	HC	MR
South Fork Winchuck	7,859	SR	50%	50%		100%			
Dominie	4,024	SR	50%	50%		100%			
Rowdy	8,342	SR	50%	50%		100%			
Little Mill	4,888	SR	50%	50%		100%			
Wilson	6,370	CKLM		50%	50%			100%	
Goose	10,250	CKLM			100%			100%	
Hunter	11,656	CKLM			100%			100%	
Terwer	21,592	CKLM			100%			100%	
Hoppaw	5,172	CKLM		100%				100%	
Waukell	2,815	CKLM		100%				100%	
McGarvey	4,867	CKLM		100%				100%	
Omagar	5,903	CKLM		50%	50%			100%	
Ah Pah	10,037	CKLM		50%	50%			100%	
Bear	6,199	CKLM		50%	50%			100%	
Surper	6,493	CKLM		50%	50%			100%	
Tectah	12,385	CKLM		25%	75%		25%	75%	
West Fork Blue	5,634	CKLM			100%			100%	
Blue	9,760	CKLM		50%	50%		75%		25%
Pecwan	15,692	KOR		50%	50%		75%		25%
Mettah	9,077	KOR		25%	75%		25%	75%	
Joe Marine	8,105	KOR		50%	50%		75%		25%
Roach	19,847	KOR		25%	75%		25%	75%	
Tully	12,727	KOR		25%	75%		25%	75%	
Panther	9,689	KOR		100%			75%		25%
Dolly Varden	13,543	KOR		100%			75%		25%
Noisy	9,719	KOR		100%			75%		25%
McDonald	2,040	KOR		100%			100%		
NF Maple	12,154	KOR		100%			100%		
Maple	18,236	KOR		100%			100%		
Coastal Tribs	7,756	KOR		100%			100%		
North Little River	6,846	KOR		100%			100%		
East Little River	7,658	KOR		100%			100%		
South Little River	11,535	KOR		100%			100%		
Lindsay	8,740	KOR		100%			100%		
Dry	9,487	KOR		50%	50%			100%	
Canon	13,566	KOR		100%			100%		
Basin	5,341	KOR		100%			100%		
Long Prairie	17,435	KOR		100%			100%		
Gosinta	5,418	KOR		100%			100%		
Boulder	17,711	KOR	50%	50%					100%
Jacoby	3,608	KOR		100%			100%		
Salmon	6,258	HUM	100%			100%			
Ryan	7,702	HUM	100%			100%			
Eel Van Duzen	7,932	HUM	100%			100%			
Plan Area Factors			10.5%	58.3%	31.2%	11.4%	44.6%	35.7%	8.3%

SC: Salmon Creek; LR: Little River; MR: Mad River, HC: Hunter Creek
SR: Smith River, CKLM: Coastal Klamath; KOR: Korbel; HUM: Humboldt Bay

Table F3-8. Pre- and post-Plan sediment delivery for the Plan Area. Sediment delivery figures represent cubic yards/year. Also included is an estimate of the sediment stabilization effort that can be achieved with an annual expenditure of $2.5 million. Road-related sediment "saved" differs from the stabilization effort because not all sediment from watercourse crossings and "other" sites is expected to deliver.

	Roads	RMZs	SMZs	SHAL-STABs	DSLs	Subtotal of All Zones	Outside of Zone	Total
Sediment Delivery--Pre-Plan	77,779	13,200	8,748	17,451	24,442	141,621	27,220	168,841
Percent of Total Sediment	46.1%	7.8%	5.2%	10.3%	14.5%	83.9%	16.1%	100.0%
Sediment Delivery--Pre-Plan/Acre[1]	4.43	0.25	1.74	0.75	0.37	0.97	0.11	0.43
Sediment Delivery--Post-Plan	3,012	10,276	6,182	11,169	24,201	54,840	27,220	82,060
Percent of Total Sediment	3.7%	12.5%	7.5%	13.6%	29.5%	66.8%	33.2%	100.0%
Sediment Delivery--Post-Plan/Acre[1]	0.17	0.20	1.23	0.48	0.37	0.37	0.11	0.21
"Natural" Sediment	0	10,241	4,374	6,981	22,832	44,428	13,610	58,038
Sediment Stabilization Effort	203,863							
Sediment "Saved"	97,648	2,924	2,566	6,282	242	109,662	N/A	109,662
Percent of Total	89.0%	2.7%	2.3%	5.7%	0.2%	100.0%	N/A	100.0%
Management Related Sediment (%)	100.0%	22.4%	50.0%	60.0%	6.6%			
Effectiveness	96.1%	22.1%	29.3%	36.0%	1.0%			
Do they fail with wood?	No	Yes	Yes	Maybe	Maybe			

[1] Calculations for roads are based on an estimate of "roaded acres" of 17,540 acres.

This simple calculation illustrates how the data in Tables F3-3, F3-4, F3-5, and F3-6 were combined to produce the non-road numbers shown in Table F3-9. Sediment delivery for roads is the next topic to be covered.

To derive an estimate of the sediment delivery associated with roads for the Plan Area it was necessary to integrate the road-related sediment delivery data provided in Appendices F1 and F2. Data presented in Appendix F1 were used to estimate road-related sediment delivery associated with shallow landslides. Data presented in Appendix F2 were used to estimate delivery from watercourse crossings as well as “other” sites. The calculations for the Plan Area are as follows:

The estimate based on Appendix F1 data (38,202 yd^3/year) only includes road-related sediment delivered from shallow landslides. This estimate was deemed to underestimate the contribution from road-related shallow landslides (not all shallow landslides can be observed on aerial photos) so a triangular distribution was developed to (1) account for this underestimate and (2) provide a range of estimates used in the Monte Carlo simulation exercise. The triangular distribution set up for the road-related shallow landslide component is shown in the VARIABLE RANGES section of this appendix (see the “Delivery from road-related landslides” assumption variable in Table F3-13) but is repeated in Table F3-9 to demonstrate the calculations. In summary, it was estimated that the road-related shallow landslide component was most likely under-represented by 15%. Thus,

$$43{,}933 \text{ yd}^3/\text{year} = 115\% \times 38{,}202 \text{ yd}^3/\text{year}$$

The minimum under-representation was thought to be 10% whereas the maximum under-representation was thought to be 30%.

Table F3-9. Road-related sediment delivery for the Plan Area.

	Watercourse Crossings (yd^3/year)	Shallow Landslides (yd^3/year)	Other Sites (yd^3/year)	Total (yd^3/year)
Minimum	16,672	42,023	911	59,607
Likeliest	31,383	43,933	1,139	76,456
Mean	31,383	45,206	1,190	77,779
Maximum	46,094	49,663	1,519	97,277
Estimate based on Appendix F1		38,202		

The expected delivery from watercourse crossings was assessed by PWA and is described in Appendix F2. PWA does not expect that all the sediment associated with high and moderate priority treatment sites (the 4,903,664 yd^3 shown in Table F3-1) will deliver within the 50-year term of the Plan. Their likeliest estimate was 32%. On an annual basis this equates to 31,383 yd^3/year. The calculation is as follows:

$$31{,}383 \text{ yd}^3/\text{year} = 32\% \times (4{,}903{,}664 \text{ yd}^3/50 \text{ years})$$

The range associated with this variable (see the “Delivery from road-related steam crossings” assumption in the VARIABLE RANGES section of this appendix) may have a minimum of 17% and a maximum of 47%, which produces the range of estimates shown in Table F3-9 (16,672 yd^3/year to 46,094 yd^3/year). Furthermore, since watercourse crossing sediment delivery is thought to be correlated with shallow landslide sediment delivery, these variables were assumed to have a correlation coefficient of 0.75 for the purposes of conducting the Monte Carlo simulation exercise. (Rainfall often initiates landslides and causes watercourse crossings to fail.)

PWA also assessed the potential sediment delivery from “other” sites. Their review resulted in the values reported in the table above. In this case, PWA expects that 60% to 100% (with the likeliest at 75%) of this sediment may deliver within the 50-year term of the Plan. The calculation of the likeliest value is as follows:

$$1{,}139 \text{ yd}^3\text{/year} = 75\% \times (75{,}956 \text{ yd}^3\text{/50 years})$$

Delivery from these “other” sites was also thought to be correlated with delivery from shallow landslides and so these variables were assigned a 0.75 correlation coefficient for the purposes of conducting the Monte Carlo simulation exercise.

Based on the mean estimates provided in Table F3-9, the total expected sediment delivery for the Plan Area from roads is the sum of three components:

Total sediment delivery from roads = sediment delivery from landslides
+ sediment delivery from watercourse crossings
+ sediment delivery from “other” sites

$$77{,}779 \text{ yd}^3\text{/year} = 45{,}206 \text{ yd}^3\text{/year} + 31{,}383 \text{ yd}^3\text{/year} + 1{,}190 \text{ yd}^3\text{/year}$$

The 77,779 yd^3/year is an important estimate and is a key figure in Table F3-8.

In addition to the variables already mentioned, several other variables associated with the landslide data and road-related sediment source studies and were assigned appropriate ranges for purposes of conducting the Monte Carlo simulation exercise. These variables and their ranges are provided in the VARIABLE RANGES section of this appendix.

Taken together, the various sources of data and sediment delivery assessments were combined to produce sediment delivery estimates for the Plan Area (Table F3-8).

From an efficiency and effectiveness perspective, the Road Implementation Plan offers a very efficient and effective means for reducing sediment delivery to watercourses (Table F3-8). It is efficient because it “saves” the greatest amount of sediment (89.0%) without setting aside merchantable trees. It is effective (96.1% effectiveness shown in Table F3-8) because approximately 90% of the high and moderate priority sites will be treated at some time during the term of the Plan and will no longer contribute sediment to Plan Area watercourses. It should be noted, however, that the Monte Carlo simulation model actually allows the effectiveness to vary between 94.2%[1] and 96.1% (see the assumption variable called Road Upgrade Effectiveness Factor in Tables F3-13 and F3-14).

Due to the model's flexible structure, Green Diamond was able to compare the efficiency, effectiveness, and economic consequences of a wide range of conservation measures. It should be emphasized, however, that the conservation needs of the covered species were deemed to be of paramount importance and scenarios (sets of conservation measures) that did not adequately meet these needs were rejected by the Plan developers.

F3.5 BENEFITS OF THE PLAN PROPOSAL

Currently, Green Diamond stabilizes sediment associated with problematic legacy road sites at an annual rate of about 82,000 cubic yards. Based on Green Diamond's anticipated harvest levels over the next 15 years, an appropriate average annual projected stabilization rate would be 81,545 cubic yards. (Note: This assumes that the relationship between harvest level and sediment stabilization effort remains constant over this period.) The expenditure of $2.5 million on an annual basis for the first 15 years of the Plan will result in the stabilization of 203,863 cubic yards of potential sediment on an annual basis over the first 15 years of the Plan. These figures are summarized in Table F3-10.

Table F3-10. A comparison of road-related sediment stabilization efforts with and without the Plan.

Year	No Plan Sediment Stabilization Program (cubic yards)	Plan Proposal Sediment Stabilization Program (cubic yards)
2002	81,545	203,863
2003	81,545	203,863
2004	81,545	203,863
2005	81,545	203,863
2006	81,545	203,863
2007	81,545	203,863
2008	81,545	203,863
2009	81,545	203,863
2010	81,545	203,863
2011	81,545	203,863
2012	81,545	203,863
2013	81,545	203,863
2014	81,545	203,863
2015	81,545	203,863
2016	81,545	203,863
Total	1,223,177	3,057,943
% of "pile of dirt"	19%	48%

1 A 94.2% road upgrade effectiveness factor implies that 85% of the high and moderate priority sites were appropriately treated during the term of the Plan.

Over the next 15 years, the two scenarios produce vastly different results. The "No Plan" scenario only stabilizes 19% of the total (i.e., 1,223,177 cubic yards divided by 6,436,482 cubic yards) whereas the Plan Proposal stabilizes 48% of the total—a 250% improvement relative to the "No Plan" scenario.

The two scenarios also have dramatically different sediment delivery rates over the next 50 years. For example, in year 15 (2016) the "No Plan" delivery rate from roads is 76% greater than the Plan Proposal delivery rate (44,754 cubic yards per year as compared to 25,463 cubic yards per year). The differences become even larger as time passes. By year 30 (2031) the "No Plan" delivery rate is 174% greater than the Plan Proposal delivery rate (23,627 cubic yards per year as compared to 8,635 cubic yards per year).

The Plan curves shown in Figure F3-2 show the road-related sediment component approaching 3,000 cubic yards during the last decade of the Plan. This implies that the Road Implementation Plan will be 96.1% effective in controlling sediment associated with high and moderate priority treatment sites.

Table F3-11 summarizes the differences between the No Plan and Plan Proposal scenarios in terms of the number of Coho generations that may benefit from an accelerated road repair program.

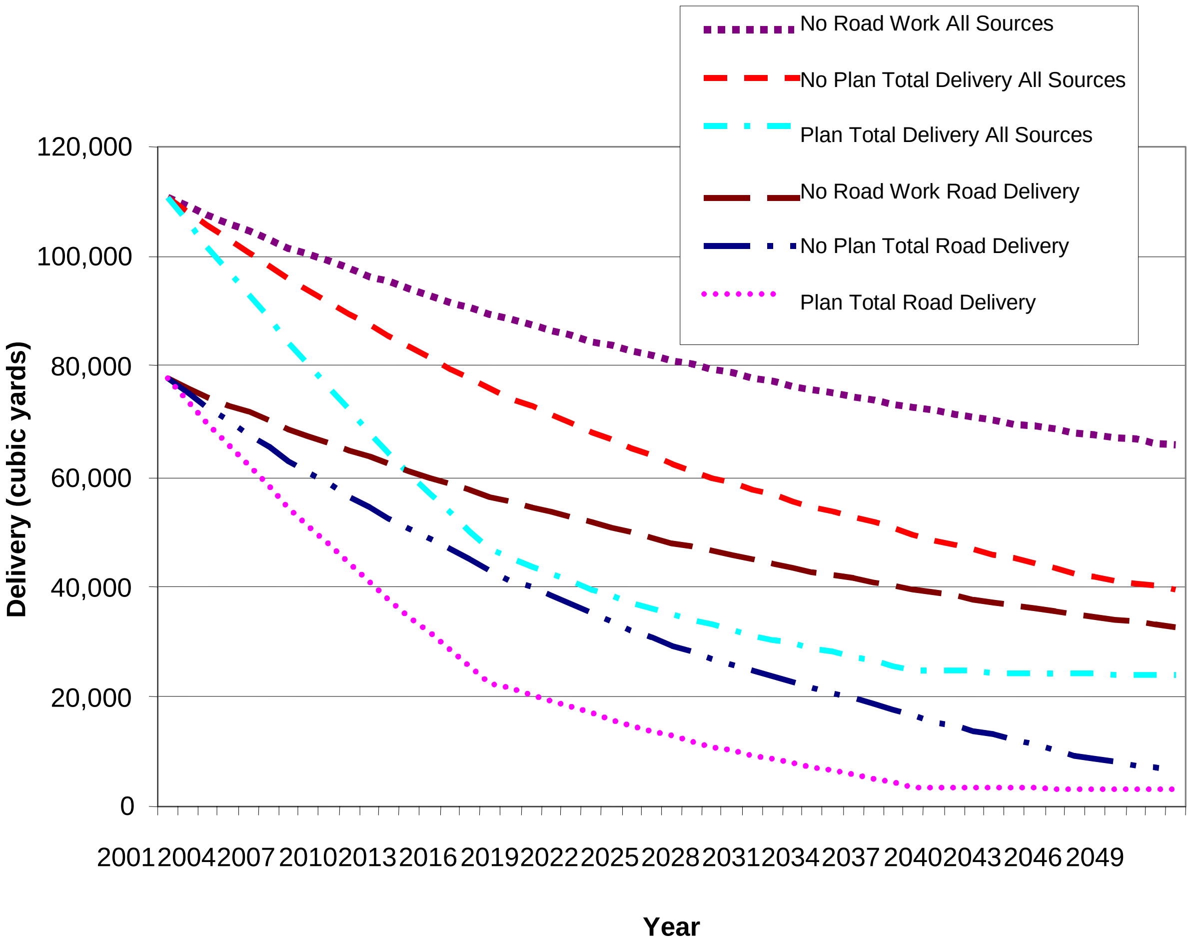
Table F3-11. Coho generations that benefit from the Plan's accelerated road repair and sediment stabilization program.

Scenario	% Pile of Dirt Stabilized	Timeframe (years)	Difference in years	No. of Coho generations that benefit
No Plan	48%	38.0		
Plan Proposal	48%	15.0	23	7.7

This type of analysis shows that the Plan's accelerated road repair and sediment stabilization program can provide benefits to approximately 7.7 generations (23 years divided by 3 years) of Coho salmon. Note that this is from road prescriptions alone. When coupled with the benefits of the other conservation measures, a greater number of fish generations benefit.

Finally, with respect to total sediment delivery from all sources, the No Plan delivery rate in year 50 is comparable to the Plan Proposal's delivery rate in year 15—a 35 year benefit (compare highlighted entries in Table F3-12).

Figure F3-2. Sediment delivery estimates over the term of the Plan. The "No Road Work" curves are based on the assumption that no money is spent repairing the high and moderate priority treatment sites over the next 50 years.



Note: Road-related sediment Includeds sediment from high and moderate priority sites only.

Table F3-12. Key sediment annual delivery rates at different points in time for both the "No Plan" and Plan Proposal scenarios.

	Year	Roads (1000 yd^3/yr)	Harvest Units (1000 yd^3/yr)	Natural (1000 yd^3/yr)	Total Delivery (1000 yd^3/yr)	Total as Compared to Background (i.e., Natural)	Roads Above Background
No Plan	0	78	33	58	169	2.9	1.3
No Plan	15	45	33	58	136	2.3	0.8
No Plan	50	7	33	58	**98**	1.7	0.1
Plan Proposal	0	78	33	58	169	2.9	1.3
Plan Proposal	15	25	24	58	**108**	1.9	0.4
Plan Proposal	50	3	21	58	82	1.4	0.1

F3.6 CALCULATION OF ACREAGE PLACED IN THE ADAPTIVE MANAGEMENT ACCOUNT

The acres within the Adaptive Management Reserve Account (AMRA) were established to address the risk associated with the management prescriptions for SMZs. Based on current GIS data, there are approximately 8,850 acres in SMZs. The acres contained within these zones will be managed using uneven-aged silviculture, defined within the Glossary of the Plan, as single tree selection. By applying single tree selection, Green Diamond will harvest approximately 65% of the conifer volume contained within these SMZs. Thus, approximately 35% of the volume will be retained within these zones to produce conservation benefits as the Plan is implemented over time. As proposed the prescriptions will represent approximately 3,100 acres (or 0.35 x 8,850 acres) of fully stocked timberland. To reduce the risk of potentially underestimating the protection needs of SMZs, Green Diamond will allow up to a 50% increase in the retained volume in SMZs. In terms of fully stocked acres, this will equate to 1,550 acres (0.50 x 3,100 acres = 1,550 acres) that can be applied to these zones. The opening AMRA balance t of 1,550 fully-stocked acres may increase or decrease in response to findings through the Effectiveness Monitoring programs outlined in Section 6.3.

F3.7 MONTE CARLO SIMULATION

The sediment delivery model for the Plan Area was subjected to a statistical procedure known as Monte Carlo simulation. This technique allows the analyst to assign ranges (or a probability density function) to key parameters (assumption variables) and to analyze the effects (the range of results) on forecast variables. The technique begins by randomly drawing parameter values from user-defined ranges and then the forecast variables are determined. This procedure is executed many times (10,000 for this exercise) and the results are saved so probability distributions can be displayed for the forecast variables. The ultimate purpose is to analyze how sensitive forecast variables are to changes in key parameters. The primary forecast variable in this exercise was an index of sediment "saved" (i.e., prevented from entering a watercourse) annually under the "No Plan" scenario as compared to the "With Plan" scenario. The benefit of using a tool like Monte Carlo simulation is that it allows the analyst to simultaneously vary a wide array of assumption variables to perform sensitivity analyses. Simplistic approaches to sensitivity analysis, like setting all assumption variables to their minimum or maximum values, may generate results in the forecast variables that are misleading because such an outcome is highly unlikely. Monte Carlo simulation produces forecast distributions that show which outcomes are most likely (the peaks in the distributions) and which outcomes are statistically unlikely (the tails of the forecast distributions).

F3.7.1 Monte Carlo Simulation Results and Variable Ranges

The complete output file from the Monte Carlo exercise is reproduced in Table F3-13. The table shows the results for the following six forecast variables:

1. Total Sediment Delivery
2. Total Sediment Stabilized
3. Road-Related Sediment Delivery
4. Road-Related Sediment Stabilized
5. No Plan Total Sediment Stabilized (compare to #2)
6. No Plan Road-Related Sediment Stabilized (compare to #4)

The first four forecast variables summarize results based on the implementation of the Plan measures. The last two forecast variables were included to provide some insight into what happens under the No Plan scenario. These No Plan forecast variables can be compared to their Plan counterparts to better understand the differences between the Plan and No Plan scenarios.

The table also includes a listing of 46 assumption variables and their ranges, some of which have been described above in this appendix. The entire output was reproduced here primarily to fully document the ranges associated with the assumption variables. The assumption variables listed in Table F3-13 are allowed to vary for a variety of reasons. The ranges associated with these assumption variables may be based on data, published literature, and/or professional judgment. Table F3-14 is included to indicate the basis for each of the assumption variables. Please review Appendix F1 and Appendix F2 for additional details.

Green Diamond assessed the differences in total sediment saved annually (over the next 15 years) under the No Plan scenario as compared to the Plan scenario. The appropriate forecast variables to inspect in Table F3-13 are “Total Sediment Stabilized” and “No Plan Total Sediment Stabilized”. A brief summary of these forecast variables is as follows:

Sediment Statistic	No Plan Total Sediment Stabilized (yd^3/year)	Plan Total Sediment Stabilized (yd^3/year)
Mean	42,575	114,973
Standard Deviation	1,534	4,801
Minimum	38,314	99,938
Maximum	47,093	129,822

These numbers indicate that the two scenarios are vastly different in a statistical sense. Note that the range of these two distributions does not overlap (i.e., the maximum No Plan value is less than the minimum of the Plan value). Thus, even considering the range (or uncertainty) of all the assumption variables, this key forecast variable shows that the Plan will result in significant sediment savings relative to the No Plan scenario.

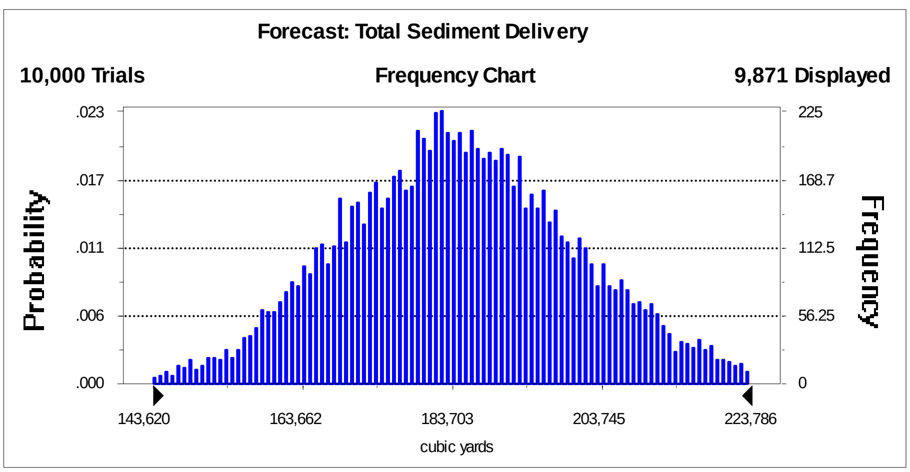
Table F3-13. Monte Carlo simulation results and assumption variable ranges. The program used to conduct the analysis is called Crystal Ball. The following is the unaltered output from that program.

Crystal Ball Report -- Option 1-SEL-b
Simulation started on 3/17/02 at 16:33:26
Simulation stopped on 3/17/02 at 16:38:31

Forecast: Total Sediment Delivery **Cell: K19**

Summary:
Display Range is from 143,620 to 223,786 cubic yards
Entire Range is from 131,750 to 263,258 cubic yards
After 10,000 Trials, the Std. Error of the Mean is 161

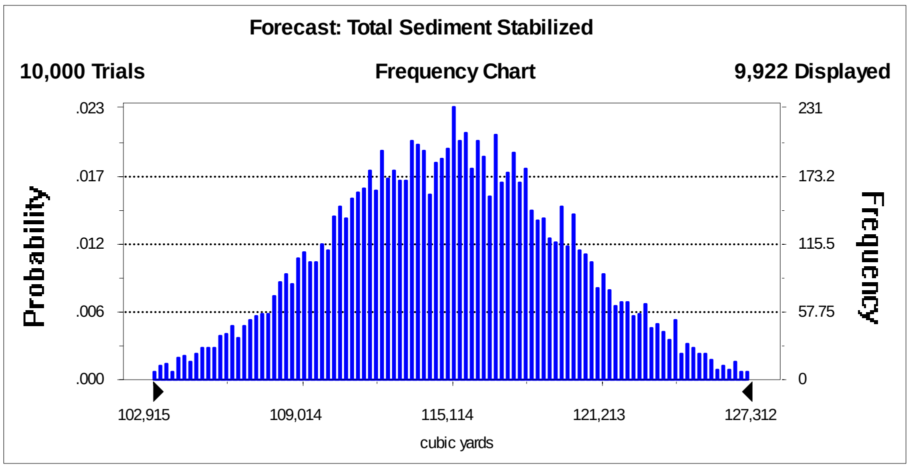
Statistics:	Value
Trials	10000
Mean	184,974
Median	184,520
Mode	---
Standard Deviation	16,070
Variance	258,234,756
Skewness	0.16
Kurtosis	3.01
Coeff. of Variability	0.09
Range Minimum	131,750
Range Maximum	263,258
Range Width	131,509
Mean Std. Error	160.70



Forecast: Total Sediment Stabilized **Cell: K25**

Summary:
Display Range is from 102,915 to 127,312 cubic yards
Entire Range is from 99,938 to 129,822 cubic yards
After 10,000 Trials, the Std. Error of the Mean is 48

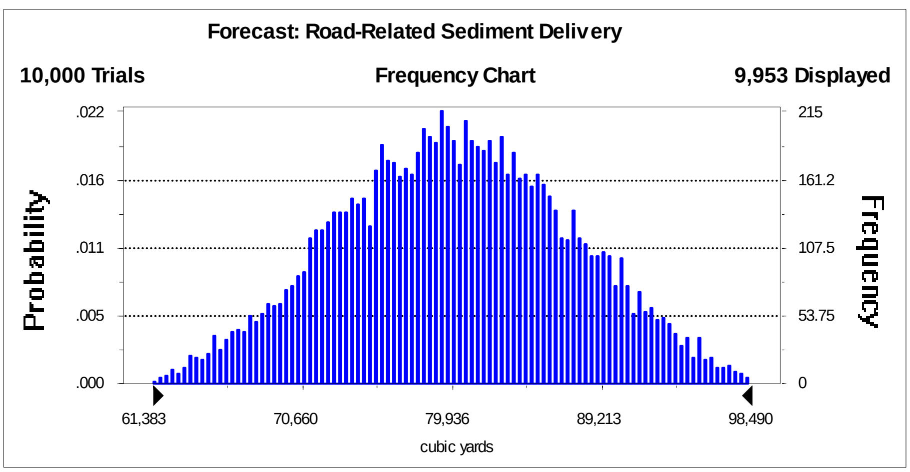
Statistics:	Value
Trials	10000
Mean	114,973
Median	115,016
Mode	---
Standard Deviation	4,801
Variance	23,047,670
Skewness	0.02
Kurtosis	2.77
Coeff. of Variability	0.04
Range Minimum	99,938
Range Maximum	129,822
Range Width	29,884
Mean Std. Error	48.01



Forecast: Road-Related Sediment Delivery **Cell: C19**

Summary:
Display Range is from 61,383 to 98,490 cubic yards
Entire Range is from 58,805 to 101,916 cubic yards
After 10,000 Trials, the Std. Error of the Mean is 73

Statistics:	Value
Trials	10000
Mean	80,183
Median	80,142
Mode	---
Standard Deviation	7,258
Variance	52,676,578
Skewness	0.02
Kurtosis	2.61
Coeff. of Variability	0.09
Range Minimum	58,805
Range Maximum	101,916
Range Width	43,111
Mean Std. Error	72.58

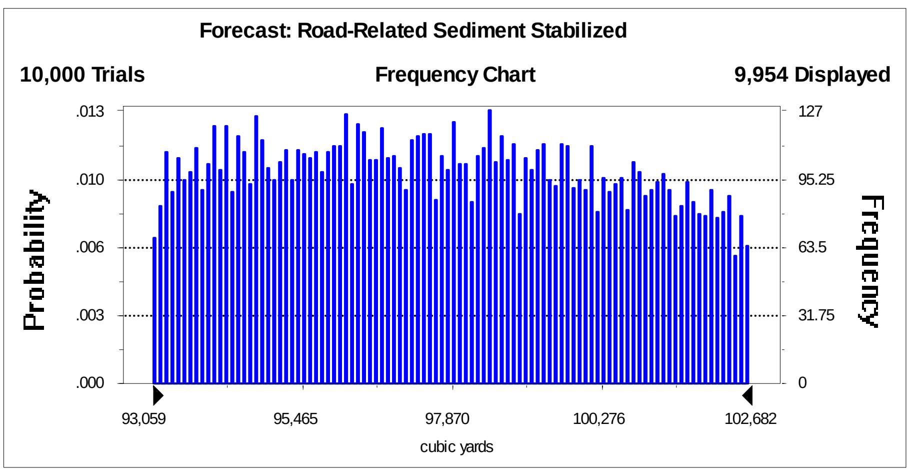


Forecast: Road-Related Sediment Stabilized **Cell: C25**

Summary:

Display Range is from 93,059 to 102,682 cubic yards
Entire Range is from 93,026 to 102,745 cubic yards
After 10,000 Trials, the Std. Error of the Mean is 27

Statistics:	Value
Trials	10000
Mean	97,705
Median	97,638
Mode	---
Standard Deviation	2,695
Variance	7,261,524
Skewness	0.07
Kurtosis	1.86
Coeff. of Variability	0.03
Range Minimum	93,026
Range Maximum	102,745
Range Width	9,719
Mean Std. Error	26.95

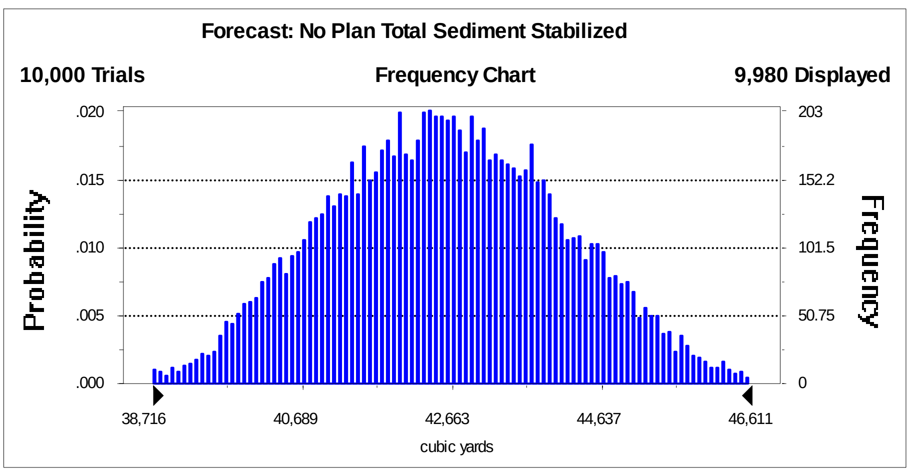


Forecast: No Plan Total Sediment Stabilized **Cell: K3**

Summary:

Display Range is from 38,716 to 46,611 cubic yards
Entire Range is from 38,314 to 47,093 cubic yards
After 10,000 Trials, the Std. Error of the Mean is 15

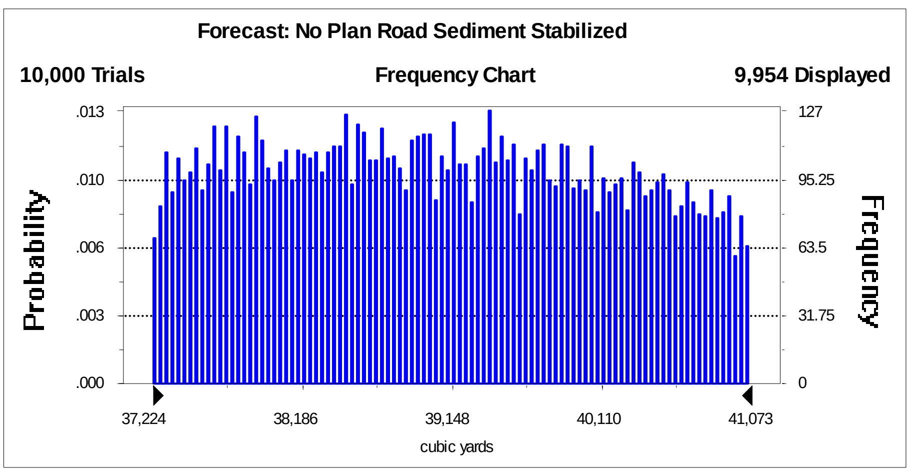
Statistics:	Value
Trials	10000
Mean	42,585
Median	42,569
Mode	---
Standard Deviation	1,534
Variance	2,353,559
Skewness	0.05
Kurtosis	2.52
Coeff. of Variability	0.04
Range Minimum	38,314
Range Maximum	47,093
Range Width	8,780
Mean Std. Error	15.34



Forecast: No Plan Road Sediment Stabilized **Cell: K1**

Summary:
Display Range is from 37,224 to 41,073 cubic yards
Entire Range is from 37,210 to 41,098 cubic yards
After 10,000 Trials, the Std. Error of the Mean is 11

Statistics:	Value
Trials	10000
Mean	39,082
Median	39,055
Mode	---
Standard Deviation	1,078
Variance	1,161,844
Skewness	0.07
Kurtosis	1.86
Coeff. of Variability	0.03
Range Minimum	37,210
Range Maximum	41,098
Range Width	3,888
Mean Std. Error	10.78



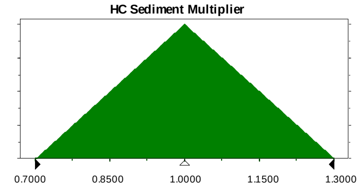
Assumption: HC Sediment Multiplier

[geology sediment model ver 7 best.xls]HC data - Cell: D26

Triangular distribution with parameters:

Minimum	0.7000
Likeliest	1.0000
Maximum	1.3000

Selected range is from 0.7000 to 1.3000



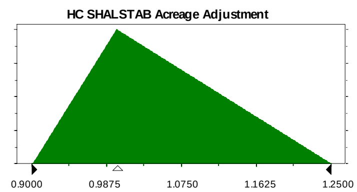
Assumption: HC SHALSTAB Acreage Adjustment

[geology sediment model ver 7 best.xls]HC data - Cell: G4

Triangular distribution with parameters:

Minimum	0.9000	
Likeliest	1.0000	
Maximum	1.2500	(=E4)

Selected range is from 0.9000 to 1.2500



Assumption: HC SMZ Acreage Adjustment

[geology sediment model ver 7 best.xls]HC data - Cell: G3

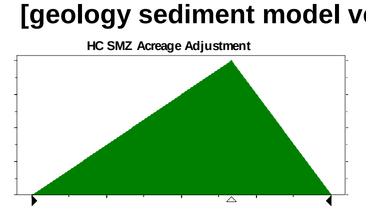
Triangular distribution with parameters:

Minimum	1.0000	
Likeliest	2.0000	
Maximum	2.5000	(=E3)

Selected range is from 1.0000 to 2.5000

Assumption: HC SMZ Acreage Adjustment (cont'd)

[geology sediment model ver 7 best.xls]HC data - Cell: G3



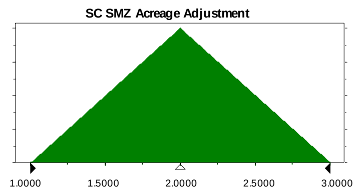
Assumption: SC SMZ Acreage Adjustment

[geology sediment model ver 7 best.xls]SC data - Cell: G3

Triangular distribution with parameters:

Minimum	1.0000	
Likeliest	2.0000	
Maximum	3.0000	(=E3)

Selected range is from 1.0000 to 3.0000



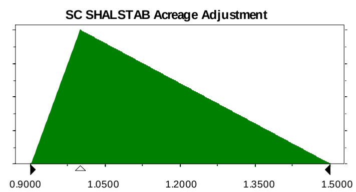
Assumption: SC SHALSTAB Acreage Adjustment

[geology sediment model ver 7 best.xls]SC data - Cell: G4

Triangular distribution with parameters:

Minimum	0.9000	
Likeliest	1.0000	
Maximum	1.5000	(=E4)

Selected range is from 0.9000 to 1.5000



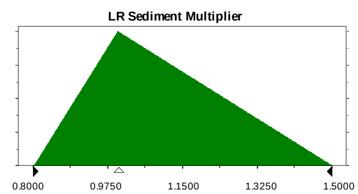
Assumption: LR Sediment Multiplier

[geology sediment model ver 7 best.xls]LR data - Cell: D26

Triangular distribution with parameters:

Minimum	0.8000
Likeliest	1.0000
Maximum	1.5000

Selected range is from 0.8000 to 1.5000



Assumption: LR SMZ Acreage Adjustment

[geology sediment model ver 7 best.xls]LR data - Cell: G3

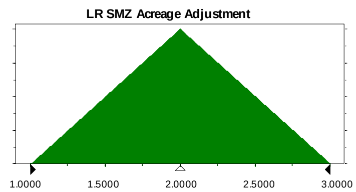
Triangular distribution with parameters:

Minimum	1.0000	
Likeliest	2.0000	
Maximum	3.0000	(=E3)

Selected range is from 1.0000 to 3.0000

Assumption: LR SMZ Acreage Adjustment (cont'd)

[geology sediment model ver 7 best.xls]LR data - Cell: G3



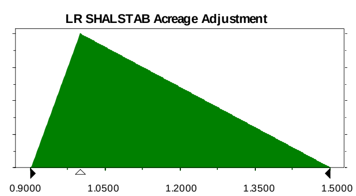
Assumption: LR SHALSTAB Acreage Adjustment

[geology sediment model ver 7 best.xls]LR data - Cell: G4

Triangular distribution with parameters:

Minimum	0.9000	
Likeliest	1.0000	
Maximum	1.5000	(=E4)

Selected range is from 0.9000 to 1.5000



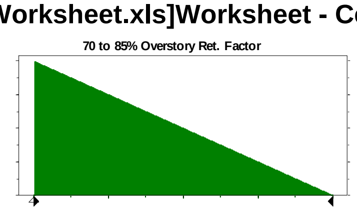
Assumption: 70 to 85% Overstory Ret. Factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S7

Triangular distribution with parameters:

Minimum	90%
Likeliest	90%
Maximum	100%

Selected range is from 90% to 100%



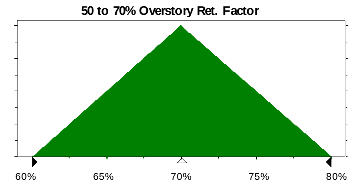
Assumption: 50 to 70% Overstory Ret. Factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S8

Triangular distribution with parameters:

Minimum	60%
Likeliest	70%
Maximum	80%

Selected range is from 60% to 80%



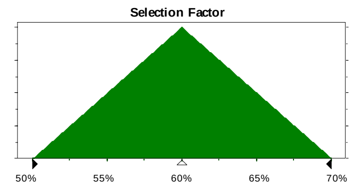
Assumption: Selection Factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S9

Triangular distribution with parameters:

Minimum	50%
Likeliest	60%
Maximum	70%

Selected range is from 50% to 70%



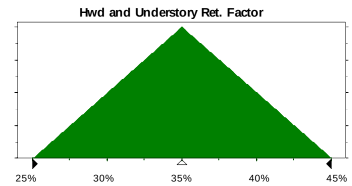
Assumption: Hwd and Understory Ret. Factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S10

Triangular distribution with parameters:

Minimum	25%
Likeliest	35%
Maximum	45%

Selected range is from 25% to 45%



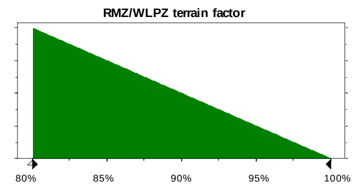
Assumption: RMZ/WLPZ terrain factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S18

Triangular distribution with parameters:

Minimum	80%
Likeliest	80%
Maximum	100%

Selected range is from 80% to 100%



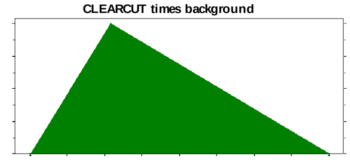
Assumption: CLEARCUT times background

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: V3

Triangular distribution with parameters:

Minimum	1.25	(=T3)
Likeliest	2.00	
Maximum	4.00	(=U3)

Selected range is from 1.25 to 4.00



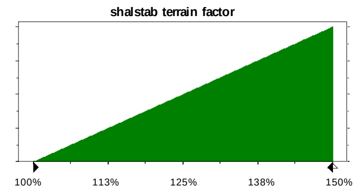
Assumption: shalstab terrain factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S21

Triangular distribution with parameters:

Minimum	100%
Likeliest	150%
Maximum	150%

Selected range is from 100% to 150%



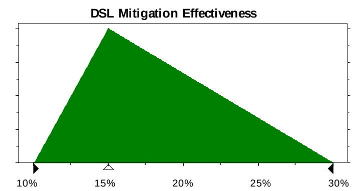
Assumption: DSL Mitigation Effectiveness

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: P27

Triangular distribution with parameters:

Minimum	10%
Likeliest	15%
Maximum	30%

Selected range is from 10% to 30%



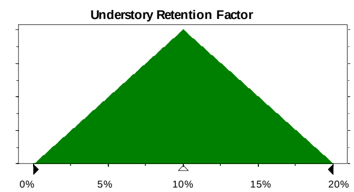
Assumption: Understory Retention Factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S11

Triangular distribution with parameters:

Minimum	0%
Likeliest	10%
Maximum	20%

Selected range is from 0% to 20%



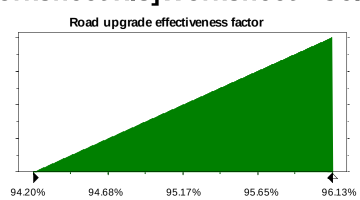
Assumption: Road upgrade effectiveness factor

[EROSION RATES by BUFFER - Worksheet.xls]Worksheet - Cell: S24

Triangular distribution with parameters:

Minimum	94.20%
Likeliest	96.13%
Maximum	96.13%

Selected range is from 94.20% to 96.13%



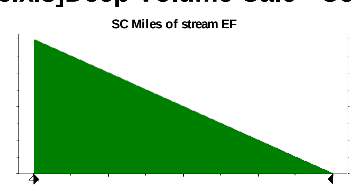
Assumption: SC Miles of stream EF

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E17

Triangular distribution with parameters:

Minimum	0.6
Likeliest	0.6
Maximum	1.1

Selected range is from 0.6 to 1.1



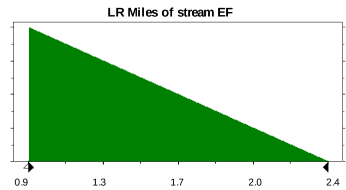
Assumption: LR Miles of stream EF

[Deep Volume Calc.xls]Deep Volume Calc - Cell: F17

Triangular distribution with parameters:

Minimum	0.9
Likeliest	0.9
Maximum	2.4

Selected range is from 0.9 to 2.4



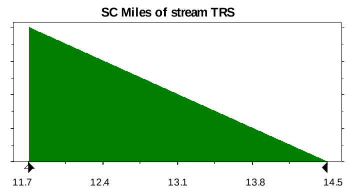
Assumption: SC Miles of stream TRS

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E18

Triangular distribution with parameters:

Minimum	11.7
Likeliest	11.7
Maximum	14.5

Selected range is from 11.7 to 14.5



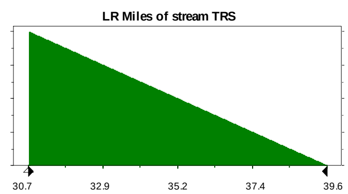
Assumption: LR Miles of stream TRS

[Deep Volume Calc.xls]Deep Volume Calc - Cell: F18

Triangular distribution with parameters:

Minimum	30.7
Likeliest	30.7
Maximum	39.6

Selected range is from 30.7 to 39.6



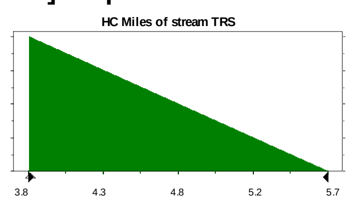
Assumption: HC Miles of stream TRS

[Deep Volume Calc.xls]Deep Volume Calc - Cell: G18

Triangular distribution with parameters:

Minimum	3.8
Likeliest	3.8
Maximum	5.7

Selected range is from 3.8 to 5.7



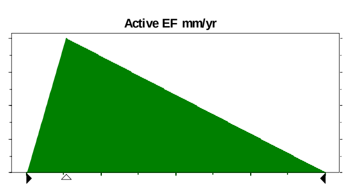
Assumption: Active EF mm/yr

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E2

Triangular distribution with parameters:

Minimum	3.00	(=J2)
Likeliest	20.00	(=K2)
Maximum	130.00	(=L2)

Selected range is from 3.00 to 130.00



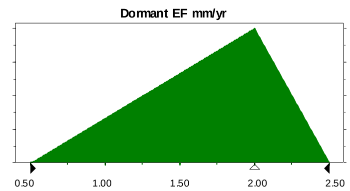
Assumption: Dormant EF mm/yr

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E3

Triangular distribution with parameters:

Minimum	0.50	(=J3)
Likeliest	2.00	(=K3)
Maximum	2.50	(=L3)

Selected range is from 0.50 to 2.50



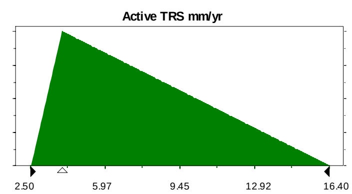
Assumption: Active TRS mm/yr

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E4

Triangular distribution with parameters:

Minimum	2.50	(=J4)
Likeliest	4.00	(=K4)
Maximum	16.40	(=L4)

Selected range is from 2.50 to 16.40



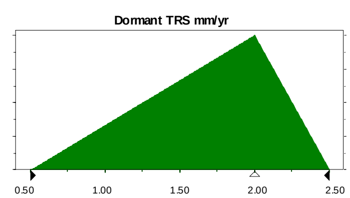
Assumption: Dormant TRS mm/yr

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E5

Triangular distribution with parameters:

Minimum	0.50	(=J5)
Likeliest	2.00	(=K5)
Maximum	2.50	(=L5)

Selected range is from 0.50 to 2.50



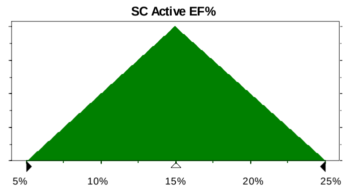
Assumption: SC Active EF%

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E11

Triangular distribution with parameters:

Minimum	5%	(=J19)
Likeliest	15%	(=J20)
Maximum	25%	(=J21)

Selected range is from 5% to 25%



Assumption: LR Active EF%

[Deep Volume Calc.xls]Deep Volume Calc - Cell: F11

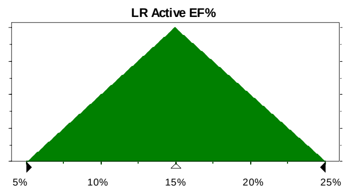
Triangular distribution with parameters:

Minimum	5%	(=K19)
Likeliest	15%	(=K20)
Maximum	25%	(=K21)

Selected range is from 5% to 25%

Assumption: LR Active EF% (cont'd)

[Deep Volume Calc.xls]Deep Volume Calc - Cell: F11



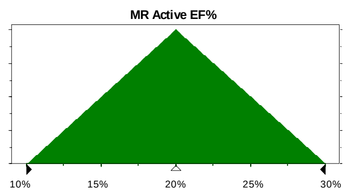
Assumption: MR Active EF%

[Deep Volume Calc.xls]Deep Volume Calc - Cell: H11

Triangular distribution with parameters:

Minimum	10%	(=M19)
Likeliest	20%	(=M20)
Maximum	30%	(=M21)

Selected range is from 10% to 30%



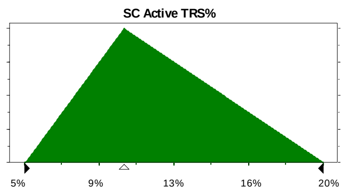
Assumption: SC Active TRS%

[Deep Volume Calc.xls]Deep Volume Calc - Cell: E14

Triangular distribution with parameters:

Minimum	5%	(=J25)
Likeliest	10%	(=J26)
Maximum	20%	(=J27)

Selected range is from 5% to 20%



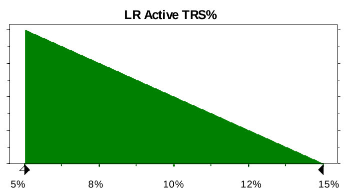
Assumption: LR Active TRS%

[Deep Volume Calc.xls]Deep Volume Calc - Cell: F14

Triangular distribution with parameters:

Minimum	5%	(=K25)
Likeliest	5%	(=K26)
Maximum	15%	(=K27)

Selected range is from 5% to 15%



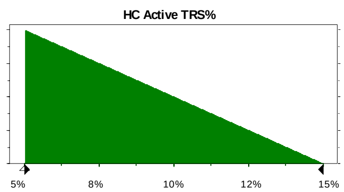
Assumption: HC Active TRS%

[Deep Volume Calc.xls]Deep Volume Calc - Cell: G14

Triangular distribution with parameters:

Minimum	5%	(=L25)
Likeliest	5%	(=L26)
Maximum	15%	(=L27)

Selected range is from 5% to 15%



Assumption: MR Active TRS%

[Deep Volume Calc.xls]Deep Volume Calc - Cell: H14

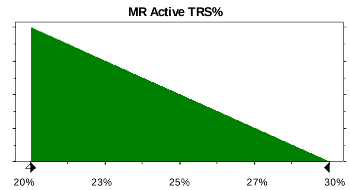
Triangular distribution with parameters:

Minimum	20%	(=M25)
Likeliest	20%	(=M26)
Maximum	30%	(=M27)

Selected range is from 20% to 30%

Assumption: MR Active TRS% (cont'd)

[Deep Volume Calc.xls]Deep Volume Calc - Cell: H14



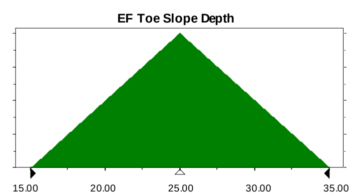
Assumption: EF Toe Slope Depth

[Deep Volume Calc.xls]Deep Volume Calc - Cell: B10

Triangular distribution with parameters:

Minimum	15.00	(=B14)
Likeliest	25.00	(=B15)
Maximum	35.00	(=B16)

Selected range is from 15.00 to 35.00



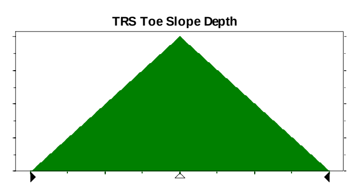
Assumption: TRS Toe Slope Depth

[Deep Volume Calc.xls]Deep Volume Calc - Cell: B11

Triangular distribution with parameters:

Minimum	30.00	(=B19)
Likeliest	40.00	(=B20)
Maximum	50.00	(=B21)

Selected range is from 30.00 to 50.00



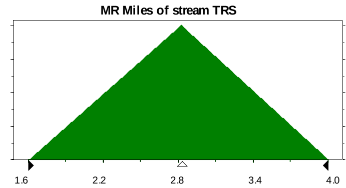
Assumption: MR Miles of stream TRS

[Deep Volume Calc.xls]Deep Volume Calc - Cell: H18

Triangular distribution with parameters:

Minimum	1.6
Likeliest	2.8
Maximum	4.0

Selected range is from 1.6 to 4.0



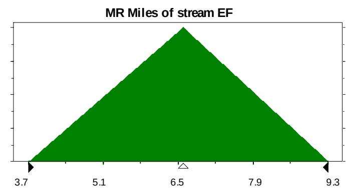
Assumption: MR Miles of stream EF

[Deep Volume Calc.xls]Deep Volume Calc - Cell: H17

Triangular distribution with parameters:

Minimum	3.7
Likeliest	6.6
Maximum	9.3

Selected range is from 3.7 to 9.3



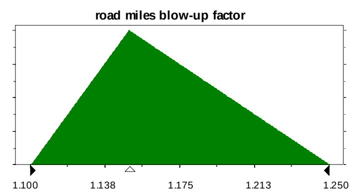
Assumption: road miles blow-up factor

[revised assessment summary ver 5.xls]data - Cell: I2

Triangular distribution with parameters:

Minimum	1.100
Likeliest	1.150
Maximum	1.250

Selected range is from 1.100 to 1.250



Assumption: Delivery from road-related landslides

[revised assessment summary ver 5.xls]removal and delivery - Cell: D22

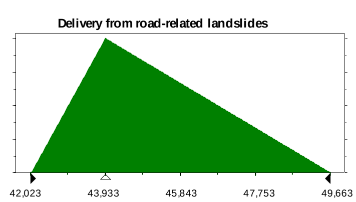
Triangular distribution with parameters:

Minimum	42,023	(=D24)
Likeliest	43,933	(=D25)
Maximum	49,663	(=D26)

Selected range is from 42,023 to 49,663

Correlated with:

Delivery from road-related other sites (F22)	0.75
Delivery from road-related stream xings (B:	0.75



Assumption: Delivery from road-related stream xings
[revised assessment summary ver 5.xls]removal and delivery - Cell: B22

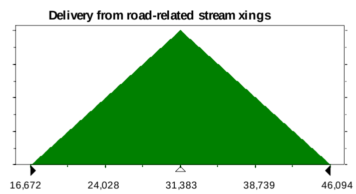
Triangular distribution with parameters:

Minimum	16,672	(=B24)
Likeliest	31,383	(=B25)
Maximum	46,094	(=B26)

Selected range is from 16,672 to 46,094

Correlated with:

Delivery from road-related landslides (D22) 0.75



Assumption: Delivery from road-related other sites
[revised assessment summary ver 5.xls]removal and delivery - Cell: F22

Triangular distribution with parameters:

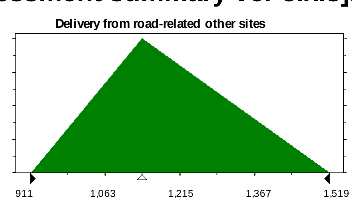
Minimum	911	(=F24)
Likeliest	1,139	(=F25)
Maximum	1,519	(=F26)

Selected range is from 911 to 1,519

Correlated with:

Delivery from road-related landslides (D22) 0.75

Assumption: Delivery from road-related other sites (cont'd)
[revised assessment summary ver 5.xls]removal and delivery - Cell: F22

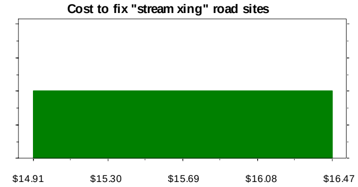


Assumption: Cost to fix "stream xing" road sites

[revised assessment summary ver 5.xls]removal and delivery - Cell: B5

Uniform distribution with parameters:

Minimum	$14.91
Maximum	$16.47



Correlated with:

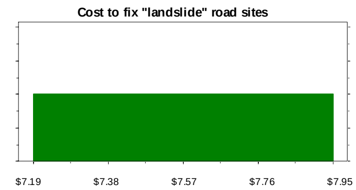
Cost to fix "landslide" road sites (D5)	0.75
Cost to fix "other" road sites (F5)	0.75

Assumption: Cost to fix "landslide" road sites

[revised assessment summary ver 5.xls]removal and delivery - Cell: D5

Uniform distribution with parameters:

Minimum	$7.19
Maximum	$7.95



Correlated with:

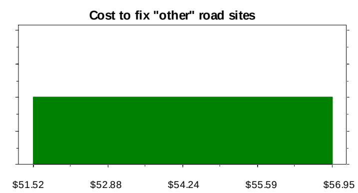
Cost to fix "stream xing" road sites (B5)	0.75

Assumption: Cost to fix "other" road sites

[revised assessment summary ver 5.xls]removal and delivery - Cell: F5

Uniform distribution with parameters:

Minimum	$51.52
Maximum	$56.95



Assumption: Cost to fix "other" road sites (cont'd)

[revised assessment summary ver 5.xls]removal and delivery - Cell: F5

Correlated with:

Cost to fix "stream xing" road sites (B5)	0.75

End of Assumptions

Table F3-14. The basis (i.e., data, literature, or professional judgment) used to determine the range of estimates for each assumption variable listed in Table F3-13. Much of the information pertaining to "hillslope" assumption variables was extracted from Appendix F1. For road-related assumption variables, information was taken from Appendix F2.

Variable No.	Assumption Variable	Hillslope or Road-Related	Basis Used To Determine Range	Comment
1	Hunter Creek Sediment Multiplier	Hillslope	Data and Professional Judgment	About 15% of the 1997 failures in Hunter Creek were field sampled to verify air photo interpretations and calibrate slide volumes and sediment delivery ratios. Range in landslide volumes estimated from 1) comparison of field and air photo measurements of landslide volumes and 2) professional judgment made from field reconnaissance and review of the historic aerial photographs.
2	Hunter Creek SHALSTAB Acreage Adjustment	Hillslope	Professional Judgment w/ limited supporting data	Range estimated from 1) comparison of the SHALSTAB map to aerial photograph interpretations of headwall swales and 2) field review of SHALSTAB areas on and off Green Diamond property.
3	Hunter Creek SMZ Acreage Adjustment	Hillslope	Professional Judgment w/ limited supporting data	The minimum is based on DEM measurements of slope gradient. Likeliest and maximum values have been increased to account for inherent underestimates of slope gradient by topographic maps and DEMs. The increase in SMZ acreage for likeliest and maximum values is estimated from 1) air photo observations, 2) limited field observations, and 3) discussions with Green Diamond forestry staff.
4	Salmon Creek Sediment Multiplier	Hillslope	Professional Judgment w/ supporting data	Limited field reconnaissance of the 1997 failures have been undertaken in Salmon Creek to verify air photo interpretations and calibrate slide volumes and sediment delivery ratios. Field reconnaissance has focused along steep streamside slopes. Range in landslide volumes is estimated from 1) comparison of field and air photo measurements of landslide volumes and 2) professional judgment made from field reconnaissance and review of the historic aerial photographs.
5	Salmon Creek SMZ Acreage Adjustment	Hillslope	Professional Judgment w/ limited supporting data	Range estimated from 1) comparison of the SHALSTAB map to aerial photograph interpretations of headwall swales and 2) field review of SHALSTAB areas on and off Green Diamond property.
6	Salmon Creek SHALSTAB Acreage Adjustment	Hillslope	Professional Judgment w/ limited supporting data	The minimum is based on DEM measurements of slope gradient. Mid and upper range have been increased to account for inherent underestimates of slope gradient by topographic maps and DEMs. The increase in SMZ acreage for likeliest and maximum values is estimated from 1) air photo observations, 2) limited field observations, and 3) discussions with Green Diamond forestry staff.

Table F3-14. (Continued)

Variable No.	Assumption Variable	Hillslope or Road-Related	Basis Used To Determine Range	Comment
7	Little River Sediment Multiplier	Hillslope	Professional Judgment w/ supporting data	Limited field reconnaissance of the 1997 failures have been undertaken in Little River to verify air photo interpretations and calibrate slide volumes and sediment delivery ratios. Field reconnaissance has focused along steep streamside slopes. Range in landslide volumes is estimated from 1) comparison of field and air photo measurements of landslide volumes and 2) professional judgment made from field reconnaissance and review of the historic aerial photographs.
8	Little River SMZ Acreage Adjustment	Hillslope	Professional Judgment w/ limited supporting data	Range estimated from 1) comparison of the SHALSTAB map to aerial photograph interpretations of headwall swales and 2) field review of SHALSTAB areas on and off Green Diamond property.
9	Little River SHALSTAB Acreage Adjustment	Hillslope	Professional Judgment w/ limited supporting data	The minimum is based on DEM measurements of slope gradient. Mid and upper range have been increased to account for inherent underestimates of slope gradient by topographic maps and DEMs. The increase in SMZ acreage for likeliest and maximum values is estimated from 1) air photo observations, 2) limited field observations, and 3) discussions with Green Diamond forestry staff.
10	Road Miles Blow-Up Factor	Road-Related	Data and Professional Judgment	Air photo analysis of Green Diamond and other property
11	Delivery From Road-Related Landslides	Road-Related	Data	Data from field inventories
12	Delivery From Road-Related Watercourse Crossings	Road-Related	Data	Data from field inventories
13	Delivery From Road-Related Other Sites	Road-Related	Data	Data from field inventories
14	Cost To Fix Watercourse Crossing Road Sites	Road-Related	Data	Field inventory, surveys, production rate estimates and standard cost rates
15	Cost To Fix Landslide Road Sites	Road-Related	Data	Field inventory, surveys, production rate estimates and standard cost rates
16	Cost to Fix Other Road Sites	Road-Related	Data	Field inventory, surveys, production rate estimates and standard cost rates

Table F3-14. (Continued)

Variable No.	Assumption Variable	Hillslope or Road-Related	Basis Used To Determine Range	Comment
17	70 to 85% Overstory Retention Factor	Hillslope	Professional Judgment w/ supporting data and literature	Adjustments to clearcut harvest ratio to account for different overstory retentions is based on professional judgment, supported by landslide inventories [e.g., ODF study on the impacts of 1995 and 1996 storms (Robison et al. 1999), PALCO Freshwater Creek Watershed Analysis (PALCO 2001a)], published literature (Megahan et al. 1978), shallow landslide modeling [e.g., (Krogstad 1995; Schmidt et al. in review; Sidle 1991; Sidle 1992; Ziemer 1981a, 1981b)], and experience.
18	50 to 70% Overstory Retention Factor	Hillslope	Professional Judgment w/ supporting data and literature	See # 17
19	Selection Factor	Hillslope	Professional Judgment w/ supporting data and literature	See # 17
20	Hardwood and Understory Retention Factor	Hillslope	Professional Judgment w/ supporting data and literature	See # 17
21	Road Upgrade Effectiveness Factor	Road-Related	Data and Professional Judgment	Data and observations from Green Diamond and other watersheds
22	RMZ/WLPZ Slope Position Factor	Hillslope	Professional Judgment w/ limited supporting data and literature	Adjustments in slope position (i.e., RMZ, SHALSTAB or other) are based on professional judgment supported by interpretations of regional landslide studies (PALCO Freshwater Creek Watershed Analysis (PALCO 2001a) and unpublished Hunter Creek landslide data) and professional experience.

Table F3-14. (Continued)

Variable No.	Assumption Variable	Hillslope or Road-Related	Basis Used To Determine Range	Comment
23	Clearcut Times Background	Hillslope	Professional Judgment and Literature	An average clearcut harvest ratio was estimated from a review of published and unpublished landslide inventories, including TMDL studies, the ODF study on the impacts of 1995 and 1996 storms (Robison et al. 1999), PALCO Sediment Source Investigations (PWA 1998a, 1998b, 1999a, 1999b), PALCO Freshwater Creek Watershed Analysis (PALCO 2001a), and Green Diamond's preliminary Mass Wasting Assessment for Hunter Creek. The results of these studies are summarized in Appendix F1, Table 5. A complete discussion of each study is included in Appendix F1 of this report. Range in clearcut ratio is based primarily on professional judgment.
24	SHALSTAB Terrain Factor	Hillslope	Professional Judgment w/ limited supporting data and literature	See #22
25	DSL Mitigation Effectiveness	Hillslope	Professional Judgment and data	The impact of harvesting on historically active deep-seated landslides is assumed to be a function of percentage of canopy retained. Landslides are mapped from the historic set of aerial photographs. The percentage of historically active slides is based on professional judgment (See #36, 37, 38, 39, 40, 41 and 42). Acreage of harvest on historically active slide determined from the GIS database. Analysis assumes clearcut harvesting on entirety of slide outside of prescribed retention areas (i.e. RMZ, SMZ, SHALSTAB, and active scarps and toes). Maximum and minimum based on professional judgment.
26	Understory Retention Factor	Hillslope	Professional Judgment	See # 17
27	Salmon Creek Miles of Stream Earth Flows	Hillslope	Data	Minimum and likeliest values based on length of streams on "Definite" and "Probable" landslides. Maximum value includes stream length on "Questionable" landslides. Certainty of landslide based on air photo observations.
28	Little River Miles of Stream Earth Flows	Hillslope	Data	See #27

Table F3-14. (Continued)

Variable No.	Assumption Variable	Hillslope or Road-Related	Basis Used To Determine Range	Comment
29	Salmon Creek Miles of Stream Translational/Rotational Landslides	Hillslope	Data	See #27
30	Little River Miles of Stream Translational/Rotational Landslides	Hillslope	Data	See #27
31	Hunter Creek Miles of Stream Translational/Rotational Landslides	Hillslope	Data	See #27
32	Active Earth Flow mm/yr	Hillslope	Literature and Professional Judgment	Maximum and minimum values based on range of measured rates of earthflow movement on the east side of the Grogan Fault in Redwood Creek (Swanson and others 1995). Likeliest value based on professional judgment supported by limited field review of slides on and off of Green Diamond property and professional experience.
33	Dormant Earth Flow mm/yr	Hillslope	Literature and Professional Judgment	Maximum and minimum values based on range of measured progressive creep rates on the west side the Grogan Fault in Redwood Creek (Swanson and others 1995). Likeliest value based on professional judgment supported by limited field review of slides on and off of Green Diamond property and professional experience.
34	Active Translational/Rotational Slides mm/yr	Hillslope	Literature and Professional Judgment	Maximum and minimum values based on measured rates of block glide movement in Redwood Creek (Swanson and others 1995). Likeliest value based on professional judgment supported by limited field review of slides on and off of Green Diamond property and professional experience.
35	Dormant Translational/Rotational Slides mm/yr	Hillslope	Literature and Professional Judgment	Maximum and minimum values based on measured progressive creep rates on the west side the Grogan Fault in Redwood Creek (Swanson and others 1995). Likeliest value based on professional judgment supported by limited field review of slides on and off of Green Diamond property and professional experience.
36	Salmon Creek Active Earth Flow %	Hillslope	Professional Judgment	Based on limited field reconnaissance of the watersheds, discussions with Green Diamond foresters and past experience.
37	Little River Active Earth Flow %	Hillslope	Professional Judgment	See #36

Table F3-14. (Continued)

Variable No.	Assumption Variable	Hillslope or Road-Related	Basis Used To Determine Range	Comment
38	Mad River Active Earth Flow %	Hillslope	Professional Judgment	See #36
39	Salmon Creek Active Translational/Rotational Slides %	Hillslope	Professional Judgment	See #36
40	Little River Active Translational/Rotational Slides %	Hillslope	Professional Judgment	See #36
41	Hunter Creek Active Translational/Rotational Slides %	Hillslope	Professional Judgment	See #36
42	Mad River Active Translational/Rotational Slides %	Hillslope	Professional Judgment	See #36
43	Earth Flow Toe Slope Depth	Hillslope	Literature and Professional Judgment	Depth based on professional judgment and experience, supported by published data on slide depth (e.g., Swanson and others 1995; SWS 1999; USACE 1980; USDA 1970).
44	Translational/Rotational Slide Toe Slope Depth	Hillslope	Literature and Professional Judgment	See #43
45	Mad River Miles of Stream Translational/Rotational Landslides	Hillslope	Data	See #27
46	Mad River Miles of Stream Earth Flows	Hillslope	Data	See #27

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